MARIE Report for March 2001

MARIE Orbit Data – Preliminary Science Report-001
Data coverage = March 13-31, 2002

Introduction

The MARIE instrument was in the stand-by mode during the majority of the cruise phase and the early part of the mapping phase. On March 13th 2002, MARIE instrument was switched back into science mode and the instrument began acquiring Mars mapping data as part of the Mars Odyssey suit of instruments. In spite of the fact that the instrument was in a stand-by and safe mode for nearly eight months (from August-2001 through April 12, 2002), it is greatly satisfying to realize that the instrument is working as expected and providing the data as designed for this extraordinary mission that provides the capability of first radiation measurements in Mars orbit.

The data obtained to date comprises the first measurements of Martian radiation environment measured from the mapping orbit for nearly two weeks during March 2002.

Data Analysis

The first set of mapping data from the MARIE instrument was downloaded on the 20th of March. About 240 files @ 40 files per down load were acquired for the March 13th –20th. A second set of data (similar number of files) was acquired for the dates March 22nd – 31st. On March 21st and 22nd, the instrument was mostly kept in the stand-by mode to facilitate the data down load operations from the Odyssey. In all, MARIE data from March 13th through March 31st (with the exception of the two days, March 21-22) was received and analyzed for this preliminary report.

From the downloaded data from the three different detectors (A, B, and C) on MARIE, particle energy and charge spectra are derived along with LET information. In the current preliminary analysis, only the dose rate (mrad/day) was determined and presented in the following Figures in time intervals of five minutes.

Model Calculations

Galactic Cosmic Rays (GCR) consists of particles of all charges from protons to uranium nuclei with energies from few MeV/nucleon to nearly 10^{15} MeV/nucleon. The flux of GCR particles is modulated by the solar activity. The modulation of the solar activity can be characterized by the deceleration parameter, phi (Ö) [1]. The phi values for a specific day were determined from the preceding 90-day measurements of neutrons available from the CLIMAX-station neutron monitor. Making use of these phi values, the GCR spectra of the Martian environment was generated with the HZETRN (High Z and Energy Transport) code [2] and particle-energy spectra, dose and dose-equivalent values were then determined for the Odyssey orbit and on the Martian mean surface.

Preliminary Results

In the Figures shown below preliminary data from MARIE are provided. Also, model calculations with the HZETRN are presented. We note that in the comparisons to the HZETRN calculations, corrections for low-energy particles (<15 MeV/u) that are not resolved by MARIE instrument have not been made. Hence the model calculations include dose contribution from these low energy particles as well.

Figures 1 and 2 present the radiation absorbed dose measurements at five-minute intervals from the current MARIE data. Figures 3 and 4 are the illustrations of the coincidence events in the MARIE instrument. Figure-5 is the comparison of the MARIE measured dose with the HZETRN model calculation. Figure-6 is the description of the SPE data as seen from the GOES8 satellite during the current data analysis time period.

Table-1 is the description of the daily averages of the MARIE measured dose (mrad/day) along with the HZETRN model calculations. Table-2 is the description of the estimated solar deceleration parameter (phi) for each day during the month of March along with the corresponding model estimated dose values.

Conclusions

- The first data set of the MARIE instrument during the mapping phase is very promising for scientific investigations of the current Martian radiation environment and for extended studies of future manned missions to the planet.
- The dose values as derived from the MARIE data are well correlated with the model calculations with differences generally less than 15% (well with in the error limits), however other important comparisons to the detailed charge, energy and LET spectra await further analysis.
- The enhancement of proton flux values and corresponding dose values of the MARIE instrument during the current data analysis time (March 13th through March 31st) seems to correlate with the observed Solar Particle Events (SPE) during this time and indicate distinct propagation of particles from sun-to-Mars compared to sun-to-Earth and thus will provide valuable data on this phenomenon for planning future Mars missions (a second SPE was recorded by MARIE during the third week of April).
- Though the SPE enhancement of the protons > 50 MeV is well correlated with the observed data by the GOES satellite, it remains a scientific challenge to explain the extent of the particle flux from the observation of the near Earth location to the Marian orbit. This challenge is due to the location of the Mars with respect to Earth at the time of these events and measurements.

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[1] Gautam Badhwar, The Radiation Environment of the Low Earth Orbit, Rad. Res. 148, S3-S10 (1997)
[2] John Wilson, Francis Badavi, Francis Cucinotta, et al., HZETRN: Description of a Free-Space Ion and Nucleon Transport and Shielding Computer Program, NASA TP-3495, May 1995.

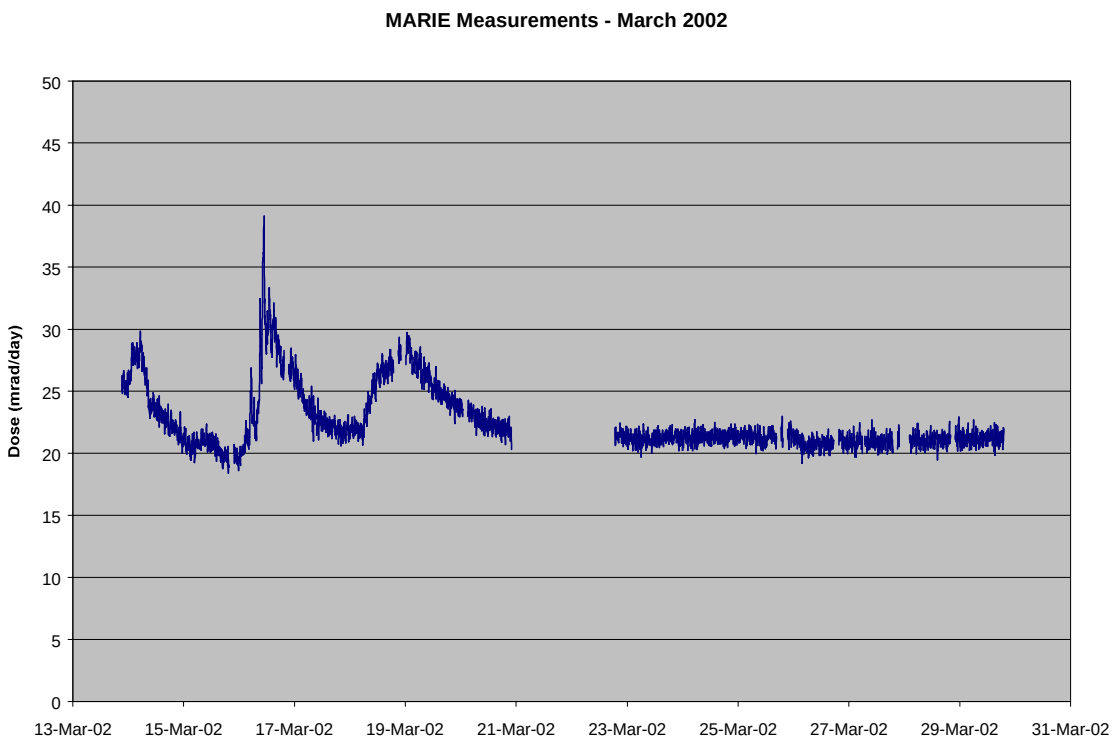

Figure-1: Radiation absorbed dose measurements by MARIE during the recent period of the mapping phase (March 13-31, 2002).

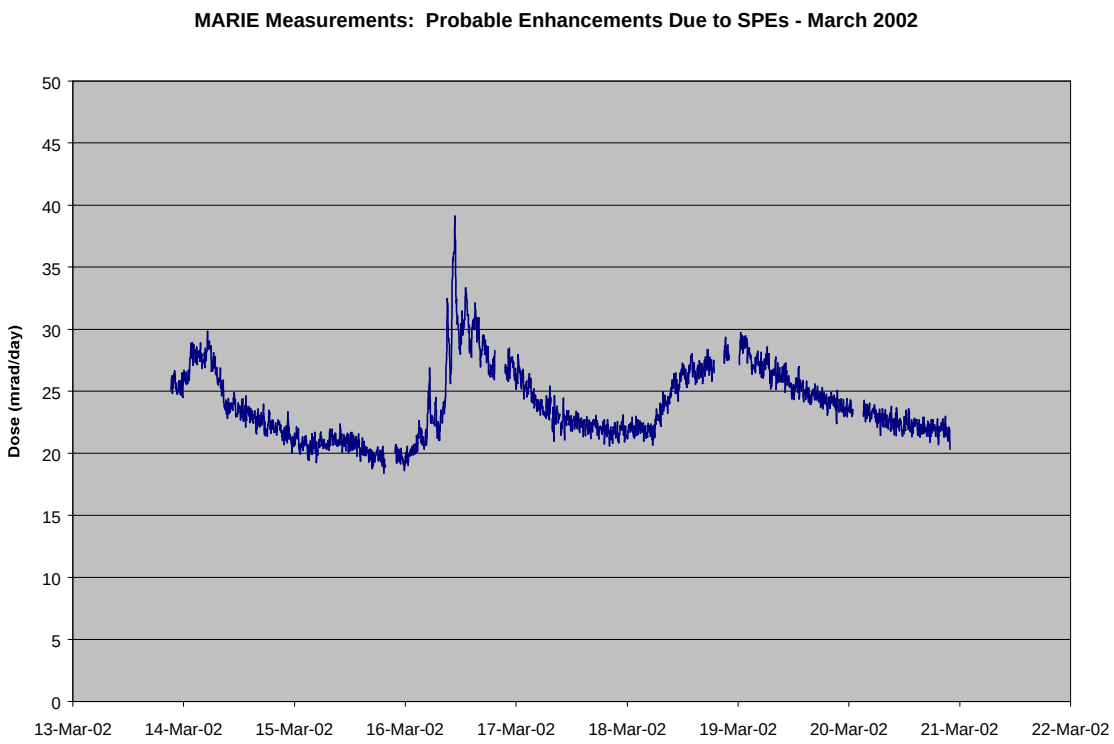

Figure-2: Radiation absorbed dose measurements during the period from March 14-22 that are probably enhanced by an SPE that was also observed at Earth on March 16-17 by the GOES satellite. Further analyses comparing the measurements of the SPE at GOES and by MARIE are underway and will be reported at a later time.

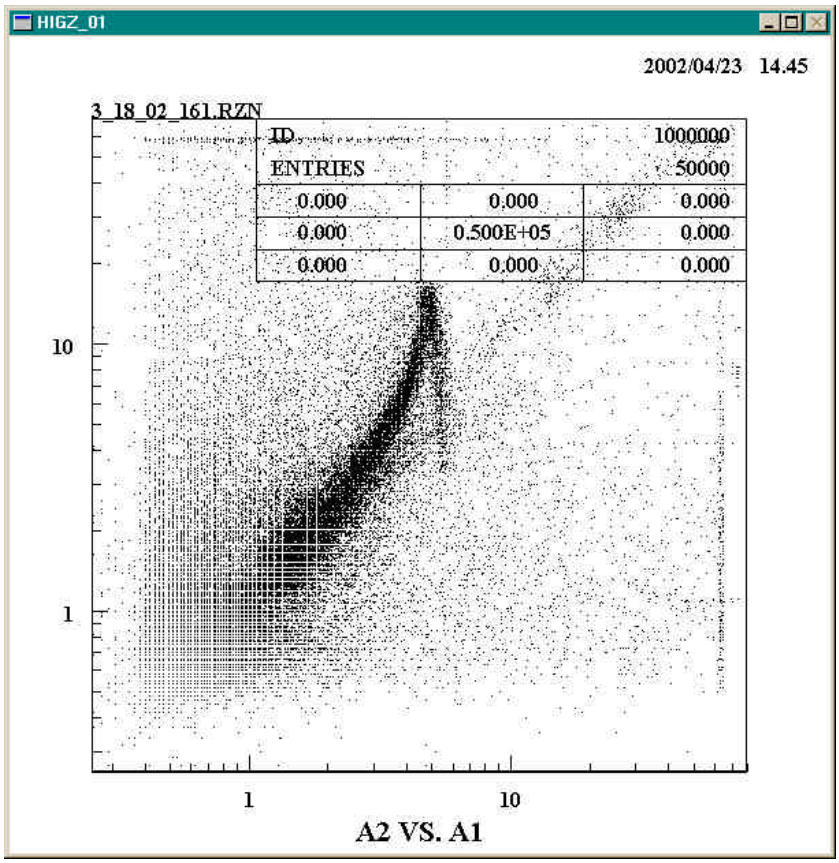

Figure-3: Examples of coincidence events measured by the MARIE instrument as observed between the A1 and A2 detectors. This scatter plot illustrates all of the triggered events as a function of the particle flux. An abundance of these events due to increased particle flux is evident from this plot on the March 18th that correlates with the higher flux of the solar energetic particles (SEP).

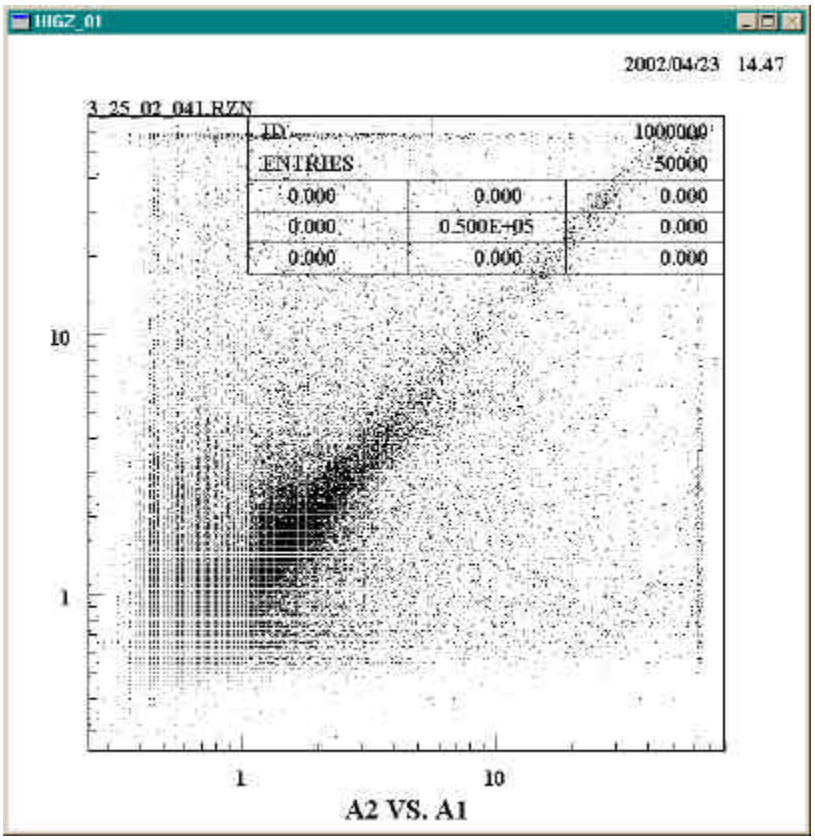

Figure-4: Particle flux counts that are measured with the A1 and A2 detectors as coincidence events during March 25th. This plot and data indicates "quiet-time" GCR flux without any enhancement of solar energy particles (SEP) as oppose to Figure-3 with increased enhancement of the particle flux.

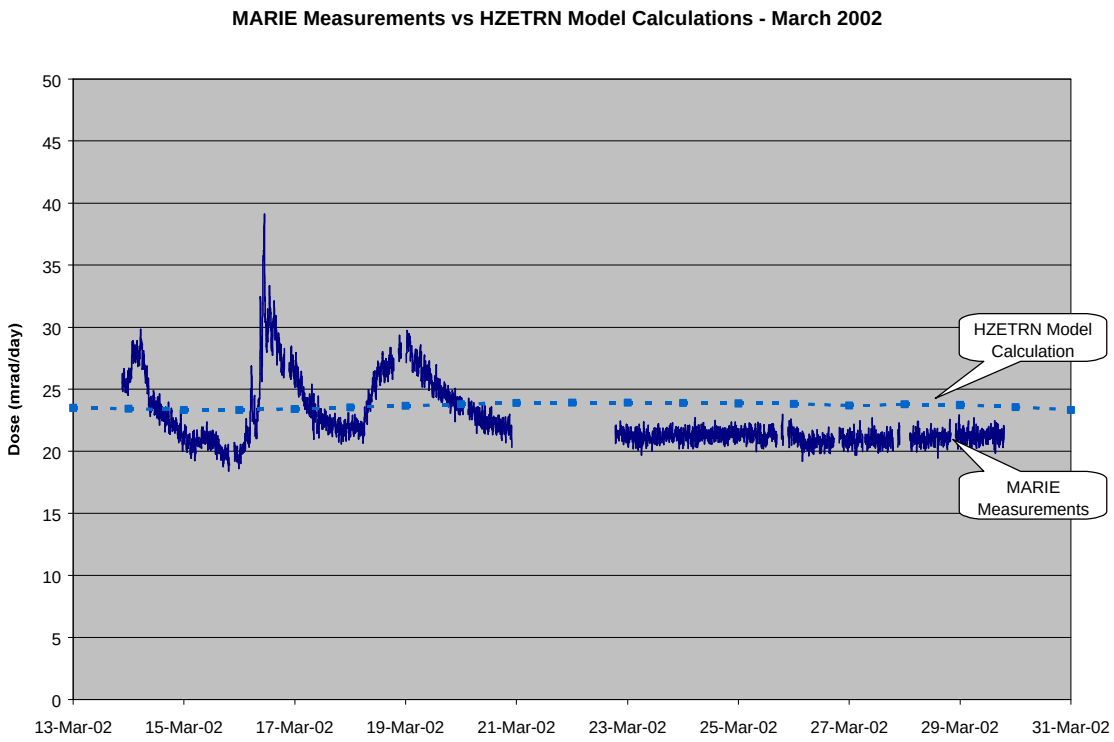

Figure-5: MARIE measured dose data is compared with the calculated dose from the HZETRN utilizing the daily solar deceleration parameter, phi for the generation of the GCR spectra.

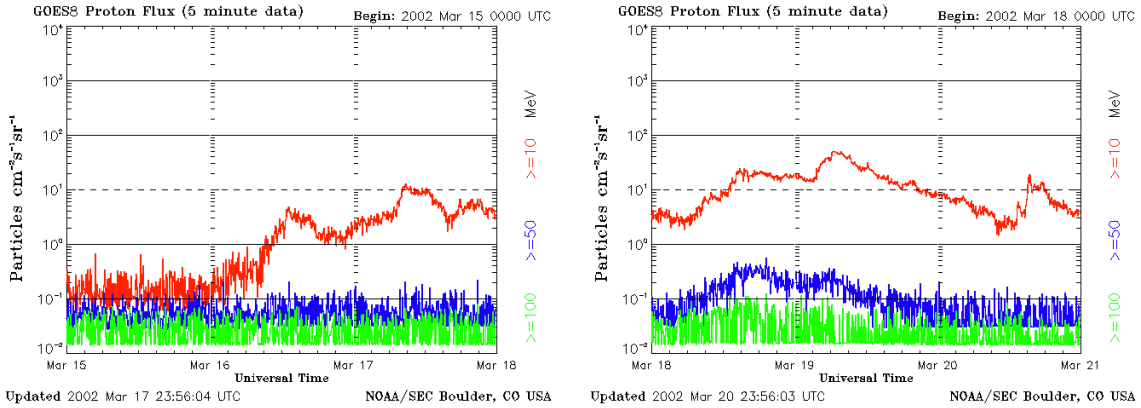

Figure-6: Enhancement of solar energetic particles (SEP) from the observed solar particle events (SPE) during March 17th and March 19th. Note the enhancements of SEPs > 50 MeV during the March 19th. This data is from the NOAA's GOES-8 satellite observation is from a near earth orbit.

Day	MARIE Measured Dose (mrad/day)	MARIE Measurment Error (SD)	HZETRN Model Dose (mrad/day)
13-Mar-02	off	off	24.15
14-Mar-02	24.48	2.5	24.03
15-Mar-02	18.76	2.0	23.85
16-Mar-02	24.06	4.4	23.86
17-Mar-02	21.96	2.1	24.00
18-Mar-02	22.42	3.3	24.19
19-Mar-02	25.81	2.0	24.42
20-Mar-02	20.46	2.3	24.64
21-Mar-02	off	off	24.79
22-Mar-02	off	off	24.83
23-Mar-02	21.28	1.3	24.85
24-Mar-02	21.48	1.3	24.82
25-Mar-02	17.86	3.3	24.76
26-Mar-02	19.01	2.0	24.68
27-Mar-02	18.20	2.8	24.50
28-Mar-02	19.27	2.1	24.64
29-Mar-02	19.48	2.0	24.56
30-Mar-02	21.55	1.5	24.28
31-Mar-02	off	off	23.90

Table-1: Measured dose values (mrad/day) from the MARIE instrument during the first data set of the Odyssey mapping phase. MARIE measurement error is shown as one S.D. considering all of the per-minute data in a 24hr time period. MARIE measured values are compared with the HZETRN model calculations. The correlation between the measured and model calculations is very good and within 10%.

Date	Observed CLIMAX Data (average over 90 days)	Estimated Phi value with CLIMAX data	HZETRN Model Calculations of Dose (mrad/day)
1-Mar-02	3758.30	984.53	23.46
2-Mar-02	3753.37	988.75	23.33
3-Mar-02	3747.82	993.50	23.19
4-Mar-02	3742.34	998.19	23.04
5-Mar-02	3736.57	1003.14	22.89
6-Mar-02	3739.51	1000.62	22.97
7-Mar-02	3754.69	987.62	23.37
8-Mar-02	3764.27	979.42	23.62
9-Mar-02	3771.60	973.14	23.81
10-Mar-02	3775.85	969.50	23.93
11-Mar-02	3779.04	966.77	24.01
12-Mar-02	3780.55	965.47	24.05
13-Mar-02	3784.52	962.08	24.15
14-Mar-02	3779.71	966.20	24.03
15-Mar-02	3773.07	971.88	23.85
16-Mar-02	3773.55	971.47	23.86
17-Mar-02	3778.61	967.14	24.00
18-Mar-02	3785.72	961.05	24.19
19-Mar-02	3794.48	953.54	24.42
20-Mar-02	3802.94	946.30	24.64
21-Mar-02	3808.55	941.50	24.79
22-Mar-02	3810.01	940.25	24.83
23-Mar-02	3810.91	939.48	24.85
24-Mar-02	3809.67	940.54	24.82
25-Mar-02	3807.56	942.34	24.76
26-Mar-02	3804.56	945.08	24.68
27-Mar-02	3797.45	951.00	24.50
28-Mar-02	3802.99	946.26	24.64
29-Mar-02	3799.75	949.04	24.56
30-Mar-02	3789.32	957.96	24.28
31-Mar-02	3774.86	970.35	23.90

Table-2: For HZETRN model calculations, deceleration parameter, phi was derived from the CLIMAX data of the NOAA satellite observations. By considering the average data for 90 days preceding the desired date, for the current negative field of the solar cycle, the phi value was determined. This phi value was utilized to generate the GCR spectra of the Martian orbit for model calculations of the dose values. Based on the variation of the phi value corresponding dose values are presented.